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A Brief Introduction to the Applications of Small Organic Molecules as Food Additives

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Part 1 Introduction to the industry of food additives

What are food additives?

As US FDA (Food and Drug Administration) states, a food additive is "any substance, the intended use of which results or may reasonably be expected to result-directly or indirectly-in it becoming a component or otherwise affecting the characteristics of any food"[1]. The definition of food additives given by Europe regulation is slightly different: "Additives are substances used for a variety of reasons - such as preservation, colouring, sweetening, etc.- during the preparation of food. The European Union legislation defines them as "any substance not normally consumed as a food in itself and not normally used as a characteristic ingredient of food, whether or not it has nutritive value"."[2]

Why they are used?

Actually, humans started using food additives long before modern definitions and regulations were put in place. Ever since mankind was able to produce more food than could be immediately consumed, people have been searching for ways to preserve the food for an extended period of time. As science and technology evolve, people have found various ways to make food last longer, more appealing, and taste better. For example, people discovered that salt and sodium nitrate could preserve meat more than 2000 years ago, and sulfur dioxide could help preserve wine over 3000 years ago.

The modern food industry involves applications of chemicals on a massive scale. The annual global market of food additives is already valued at about 40 billion dollars[3]. Data Show that the consumption of processed food has been soaring across the world in recent years.[4] Nowadays, customers often take in various food additives without even knowing it. Food additives are found in fresh fruits, meat, seafood, low-fat or fat-free dairy products, canned food, frozen food, et cetera. All these food products are made possible because of a wide range of food additives applied to them.

Although synthetic chemicals are heavily involved in modern food additives, it is unfair to think that the food additives are all "bad" and unnecessary. In this chapter, we will study some basic chemical concepts regarding the food additives as well as their applications. The goal is to provide a better understanding of food additives from a chemical point of view.

Categories of food additives

In general, food additives serve at least one of the following functions. In each category, food additives are further divided into different families based on their working mechanisms.

1. To maintain or improve safety and freshness.

   - **Preservatives:** To prevent bacteria, fungi, yeast to grow in the food.
   - **Antioxidants:** To prevent the oxidation of oil and fat molecules and the formation of rancid compounds. To prevent fresh cut fruits turning brown.

2. To improve or maintain nutritional value.

   - **Vitamins, minerals and fibers**: To enhance the quality of a food by making up the lacking nutrients. Addition of these additives helps fight malnutrition worldwide.

3. To improve taste, texture and appearance:

   - **Natural or artificial flavor enhancers**
   - **Colors**
   - **Sweeteners**
   - **Thickeners, emulsifier, stabilizers and gelling agents**
   - **Anti-caking agents**
   - **Antioxidants**

How are chemicals approved to use as food additives?

Food and Drug Administration (FDA) has to consider the following factors before approving any substance as a legal food additive: the chemical properties of the substance; the amount of the substance that would be consumed; long-term and short-term health effect. The decisions are made based on the most updated data available. As science advances, FDA may modify their regulations accordingly. In October 2018, FDA banned seven synthetic food additives that had been used as flavor enhancers in bakery products, ice creams, and beverages[5]. These banned food additives include myrcene, an alkene molecule that gives beer a peppery and balsam aroma, and pulegone which is often used for its minty scent.

Part 2 Understanding chemical terminology used in food additives

IUPAC names - We have discussed how to name different organic compounds according to the IUPAC rules throughout this course. The IUPAC nomenclature in organic chemistry is a system by which organic compounds are named as recommended by the International Union of Pure and Applied Chemistry (IUPAC). Sometimes IUPAC names are used on the food labels when the names are short enough and there are no other common names assigned to the compound. Benzoic acid, a commonly used preservative, is an example of IUPAC name directly listed on food labels.

Common names - Common names are how people call certain chemicals in everyday life, especially for the compounds that have been discovered and used by people throughout the history long before the IUPAC system was in place. For example, we do not usually use the IUPAC name 2,4,6-trinitrotoluene, instead we just call this compound TNT. Almost no one uses the name 1,3,7-trimethylpurine-2,6-dione because caffeine is a much more recognized name. Probably, the most used common names on food labels are the ones designated to sugars. Instead of using specific names like glucose or fructose for saccharides and indicating their concentrations in foods, we just call them maple syrup, high fructose corn syrup, agave nectar, etc.

Commercial names – Besides IUPAC names and common names, there are also commercial names for some organic compounds. These names are not only used in food industry but also, more frequently, used in pharmaceutical industry. Commercial names are trade names or brand names. For example, Advil® (commercial name) is a painkiller because its active ingredient is ibuprofen (common name), and the IUPAC name for this compound is (RS)-2-(4-(2-methylpropyl) phenyl) propanoic acid.

LD_{50}, LC_{50}, and IC_{50} value[6] – LD stands for "Lethal Dose". LD_{50} is the amount of a material, given all at once, which causes the death of 50% (one half) of a group of test animals. LD_{50} is very useful in measuring the short -term poisoning potential or acute toxicity of a substance. The substance can be delivered orally, dermally or via injection. The unit is usually milligram per 100 grams for small animals, or per kilogram for large animals. The most common test subjects listed on the SDS data sheet are rats or mice.

LC stands for "Lethal Concentration". LC values usually refer to the concentration of a chemical in air. But in environmental studies, it can also mean the concentration of a chemical in water. The concentration of the chemical in air that kills 50% of the test animals during the observation period (usually 4 hours) is the LC_{50} value. The test animals are clinically observed for up to 14 days.

Both LD_{50} and LC_{50} values indicate the acute toxicity of a substance. If a substance is a known carcinogen, the information will be listed separately on the SDS.

There is another term called "**IC_{50}**". IC stands for inhibitory concentration. IC_{50} is the half of maximal inhibitory concentration. The IC_{50} is a measure of the potency of a substance in inhibiting a specific biological or biochemical function. This value is more often seen in pharmacological research field as aa assessment of drug potency.

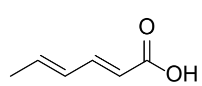
SDS/MSDS data sheet –The safety data sheet (SDS) and material safety data sheet (MSDS) are essentially the same. They both document the dangers, composition, safe handling, and disposal of said chemicals and substances. The name SDS refers to a safety data sheet that is constructed with a standardized 16-section format arranged in a strict order according to the regulation of UN's globally harmonized system (GHS). These data sheets are extremely important tools for the public to understand the structural features, chemical properties and the toxicity of the substances listed on food labels. All chemical vendors are required to provide complete SDS on the chemicals they sell. Companies such as VWR, Fisher scientific, Sigma-Aldrich are usually good resources to locate the SDS needed. Both common names and IUPAC names can be used to search for SDS or MSDS of a certain substance.

Part 3 A brief introduction to some organic compounds commonly used as food additives

3.1 Preservatives

Preservatives are probably the most important food additives. Although the general public may not have a positive impression on food preservatives, it is impossible to supply safe and fresh food to people without using them. To clarify some of the misapprehension about preservatives, let us look at two chemicals that are commonly used as food preservatives from the perspective of organic chemistry.

- **Sorbic acid and its salts**



Sorbic Acid
Chemical Formula: $C_6H_8O_2$
Molecular Weight: 112.13

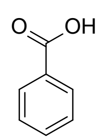
Sorbic acid is a common name. The IUPAC name for this compound is **(2E,4E)-hexa-2,4-dienoic acid**. Sorbic acid naturally exists in a variety of fruits and plants. Sorbic acid and its salt like potassium sorbate and calcium sorbate can often be seen listed on food labels. They are mostly used in sauces, jelly and canned food. Since they are "natural organic compounds", which means they were first discovered in nature rather than synthesized in a laboratory, people have a more positive view of them. Actually, the sorbic acid widely used in the food industry is indeed chemically synthesized, and its chemical structure is exactly the same as the natural sorbic acid found in nature.

Sorbic acid can prohibit the activities of some bacteria, fungi and yeast enzymes, thus significantly prolonging the shelf life of the food[7]. Usually, the concentration of sorbic acid needs to reach 0.1% -0.3% in the food to serve its purpose. For every pound of that food you consume, you take in around 0.9 grams of sorbic acid. Let us compare some interesting data from the SDS datasheet of sorbic acid and those from table salt, sodium chloride.

Sodium Chloride (Table Salt)[8]	**Sorbic Acid**[9]
May cause eye, skin, and respiratory tract irritation.	Causes skin irritation Causes serious eye irritation May cause respiratory irritation
LD_{50}/LC_{50}: Oral, rat: LD_{50} = 3000 mg/kg	**LD_{50}/LC_{50}:** Oral, rat: LD_{50} = 3200 mg/kg

The data show that sorbic acid is more irritating than sodium chloride. This is easily understandable because sorbic acid is a real carboxylic acid with a pKa of 4.76, which is the same as acetic acid, a major component in vinegar. Sodium chloride is a neutral salt formed from the neutralization reaction between a strong acid and a strong base. LD_{50} data suggest that, if we only consider the acute effect, sorbic acid is actually **LESS** toxic than table salt. In fact, sorbic acid is considered a very safe additive.

- **Benzoic acid and its salt**



Benzoic Acid
Chemical Formula: $C_7H_6O_2$
Molecular Weight: 122.12

Benzoic acid is indeed an IUPAC name. It is widely used as food preservatives in acidic foods and drinks, especially in carbonated beverages because benzoic acid presents the strongest antibacterial activity at low pH. The concentration of benzoic acid ranges from 0.05% to 0.1%. Its salt forms, sodium benzoate and potassium benzoate, are also very common food preservatives.

In previous chapters, we discussed the aromatic compounds and some of their physical and chemical properties. Benzene is the first example we use to explain aromaticity. When it comes to safety, benzene is highly toxic and an infamous carcinogen known to human. Interestingly, benzoic acid has been used as a common food additive, although it contains a benzene ring in its structure. Again, let us study some facts about benzoic acid and benzene from their SDS data sheets.

Benzene[10]	Benzoic Acid[11]
Eye: Causes eye irritation. **Skin:** Causes skin irritation. Harmful if absorbed through the skin. Prolonged and/or repeated contact may cause defatting of the skin and dermatitis. **Ingestion:** May cause central nervous system depression, characterized by excitement, followed by headache, dizziness, drowsiness, and nausea. Advanced stages may cause collapse, unconsciousness, coma and possible death due to respiratory failure. May cause effects similar to those for inhalation exposure. Aspiration of material into the lungs may cause chemical pneumonitis, which may be fatal. **Inhalation:** Causes respiratory tract irritation. May cause drowsiness, unconsciousness, and central nervous system depression. Exposure may lead to irreversible bone marrow injury. Exposure may lead to aplastic anemia. Potential symptoms of overexposure by inhalation are dizziness, headache, vomiting, visual disturbances, staggering gait, hilarity, fatigue, and other symptoms of CNS depression.	**Eye:** Causes severe eye irritation. Causes redness and pain. **Skin:** Causes skin irritation. May be harmful if absorbed through the skin. May cause sensitization by skin contact. May be absorbed through the skin in harmful amounts. Absorption through the skin has produced labored breathing in humans. Benzoic acid can cause redness and swelling with itching (non-immunological contact urticaria or hives) in most people at the site of application. Individuals can react without having been previously exposed to benzoic acid. **Ingestion:** Harmful if swallowed. May cause irritation of the digestive tract. **Inhalation:** Causes respiratory tract irritation. May be harmful if inhaled. May cause respiratory sensitization. Intermittent breathing of dust over a 4-week period produced interstitial fibrosis in the lungs of rats. Benzoic acid begins to sublime at 100°C.
Chronic: May cause bone marrow abnormalities with damage to blood forming tissues. May cause anemia and other blood cell abnormalities. Chronic exposure to benzene has been associated with an increased incidence of leukemia and multiple myeloma (tumor composed of cells of the type normally found in the bone marrow). Immunodepressive effects have been reported. This substance has caused adverse reproductive and fetal effects in laboratory animals.	**Chronic:** Prolonged or repeated skin contact may cause dermatitis.
LD_{50}/LC_{50}: Oral, rat: LD_{50} = 930 mg/kg	**LD_{50}/LC_{50}:** Oral, rat: LD_{50} = 1700 mg/kg
Carcinogenicity ACGIH: A1 - Confirmed Human Carcinogen California: carcinogen, initial date 2/27/87 NTP: Known carcinogen IARC: Group 1 carcinogen	**Carcinogenicity** Not listed by ACGIH, IARC, NTP, or CA Prop 65.

As we discussed before, structures determine properties. A small change to the structure of an organic compound may cause a drastic change in its toxicity.

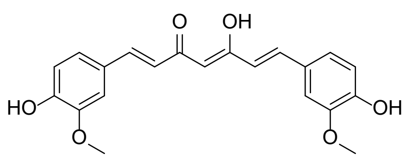
3.2 Colors

Foods are often more appreciated if they are visually appealing. The fact is people eat with their eyes, too. In many cases, you are already "eating" the food before you put it in your mouth. Color and taste are inseparable. Would you drink colorless orange juice? Or eat gray ketchup? Food dyes are chemicals used to give foods desired colors and, because of this, their use can be controversial. Some people tend to think they serve a purpose of deception by changing the natural color of the food. There are two types of food colors, certified colors and colors exempt from certification. The certified colors are from synthetic compounds, which means these compounds need to be tested for safety before they can be used in food industry. Colors derived from natural sources are exempt from certification since they have already been part of human food source for a long time. Natural colors usually cost more than synthetic ones.

Nature Colors:

The two most commonly used natural food dyes are curcumin and riboflavin.

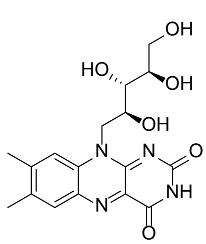
- **Curcumin**



Curcumin
Chemical Formula: $C_{21}H_{20}O_6$
Molecular Weight: 368.39

Curcumin is an extract from several plants in the ginger family. Curcumin not only has bright yellow colors but also shows numerous bio-activities[12,13,14]. One of the bioactivities is being an antioxidant. We discussed the antioxidant properties of phenol in the chapter of aromatic compounds. As you can see, curcumin belongs to the family of aromatic antioxidants. Curcumin is also a pH indicator. The phenolic hydrogens are acidic and prone to deprotonation. The resulting oxygen anion absorbs light at a different wavelength and presents a new color. If you add basic substance to mustard, it will turn red. On the other hand, the carbonyl group in curcumin is capable of receiving a proton, which makes curcumin a base.

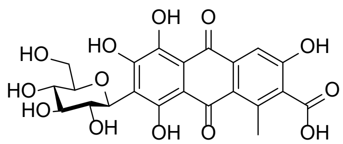
- **Riboflavin – Vitamin B2**



Riboflavin
Chemical Formula: $C_{17}H_{20}N_4O_6$
Molecular Weight: 376.37

Riboflavin has another name, Vitamin B2. It also has an orange-yellow color. In this case, using riboflavin as the food dye can actually enrich the nutritional characteristics of the food.

- **Carminic Acid**



Carminic acid
Chemical Formula: $C_{22}H_{20}O_{13}$
Molecular Weight: 492.39

Another interesting natural dye is carminic acid. This deep red compound is extracted from cochineal, a bug that is indigenous to south America. Since it is from a natural source, cochineal extract is approved for food dyeing in a variety of products, such as meat, alcoholic drinks, cookies, some cheddar cheese, etc. Next time you open a bottle of ketchup or strawberry-flavored yogurt, look for carminic acid, carmine, cochineal, or Natural Red 4 on the label. Just checking to see whether there is bug in your food.

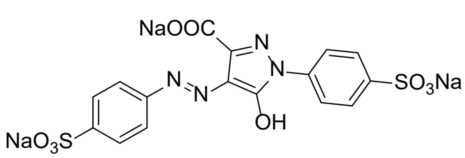
Artificial Dyes:

Artificial dyes include a much larger number of synthetic compounds. And the colors cover almost the whole spectrum. A major reason for synthetic dyes is that they often cost only a fraction of the natural dyes do. Besides, synthetic dyes have a longer shelf life. Let us take a closer look at one of the biggest families of synthetic dyes: Azo dyes. They are synthetic compounds characterized by one (mono azo) or several intramolecular N=N double bonds. Like the natural dyes, these synthetic dyes are molecules with extensive conjugation structures and can absorb light from the visible spectrum. By modifying the structures, scientists can tune the energy needed for electron excitation and achieve a desired color.

Azo dyes can be found in a wide range of foods including Cheetos, Sunkist soda drinks, cheese products, and candies. Among seven synthetic food dyes approved by administration, three of them are azo dyes. Chances are you can easily find their names on one (or more than one) of the food labels in your kitchen.

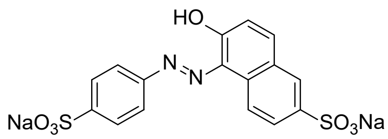
Here are some examples of azo dyes that are widely used in food industry:

- **Yellow 5 – Tartrazine**



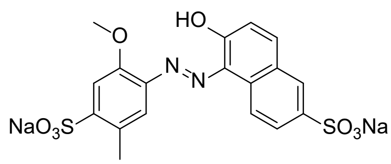
Yellow 5 - Tartrazine
Chemical Formula: $C_{16}H_9N_4Na_3O_9S_2$
Molecular Weight: 534.36

- **Yellow 6 - Sunset Yellow**



Yellow 6 - Sunset Yellow
Chemical Formula: $C_{16}H_{10}N_2Na_2O_7S_2$
Molecular Weight: 452.36

- **Red 40 - Allura Red AC**



Red 40 - Allura AC
Chemical Formula: $C_{18}H_{14}N_2Na_2O_8S_2$
Molecular Weight: 496.42

Over the years, more and more information about the azo dyes has been collected, which prompts people to choose safer dyes for foods. Some azo dyes were previously considered safe, but are now banned because studies have shown their connection to toxic effects[15]. It is not that these dyes themselves are toxic, but the metabolites generated in enzymatic reactions have negative effects on human health. These enzymes can be found in various bacteria including the ones that live in our intestinal system. Some of the metabolites are known mutagenic or carcinogenic agents, such as aniline, toluene, benzidine and other small aromatic amine molecules[16].

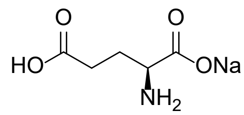
Although yellow 5, yellow 6 and red 40 are still permitted in united states and Europe, there are a series of ongoing investigations in progress to study the full effects of azo dyes on human health in a systematic manner. For example, these studies include effects of the azo dyes on the expression of certain genes and their roles in induction of hypersensitivity in immune systems.

3.3 Flavor enhancers

Flavor enhancers are extremely important in modern food industry. They do not usually have distinctive flavors or tastes, but they can either bring out or improve the tastes of the foods. There are several basic flavors in food that can be picked up by our taste buds: sour, sweet, bitter, hot, and umami. As we mentioned in the ester chapter, ester molecules mimic a variety of fruit and flower flavors such as banana, rose, apple and oranges.

One of the most commonly used flavor enhancers is MSG – Monosodium Glutamate. This simple sodium salt of an amino acid has attracted so much public attention and become a very controversial substance to use in the food.

- **MSG – Monosodium Glutamate**



MSG
Chemical Formula: $C_5H_8NNaO_4$
Molecular Weight: 169.11

Glutamic acid is a nonessential amino acid, which means that it can be synthesized in humans at a reasonable rate. Another natural source of glutamic acid is from various foods, such as tomato, seaweed and cheese. Humans have been consuming glutamate-rich foods for thousands of years. The glutamate in flavor enhancers is chemically identical to the glutamate present in foods. After taken into humans, they are metabolized exactly the same way. FDA considers the addition of MSG to foods as "generally recognized as safe" (GRAS). Although some people report that they are sensitive to MSG and have so called "Chinese Restaurant Syndrome", scientists have not been able to establish a connection between MSG and the symptoms. So far, only a few papers indicated that a very high dosage of MSG intake could damage the brains of infant rats[17] and might link to human headache and muscle pain.

There are two more interesting facts about MSG:

1. FDA states that foods with any ingredient that naturally contains MSG cannot claim "No MSG" or "No added MSG" on their labels.
2. Gluten and glutamate have nothing to do with each other although the names may seem similar. Gluten is a mixture of proteins that naturally exist in flours. Glutamate is the ionic form of an amino acid.

3.4 Sweeteners

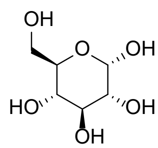
Sweeteners can be actual sugar compounds that have calories in them or sugar substitutes that are energy free.

Saccharides:

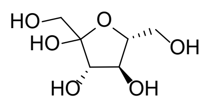
The saccharides or the sugar chemistry is one of the most studied fields in organic chemistry. We have discussed the structures of some saccharides and their chemical properties in the chapters of stereochemistry and carbonyl compounds. Now let's look at the most commonly used sugar sweetener in food: high fructose corn syrup (HFCS). As people become more aware of what they consume, this ingredient has also gained much public attention over the years.

- **High fructose corn syrup (HFCS)**

High fructose corn syrup is made from corn starch. Starch is a long-chain polysaccharide that can be broken down into small sugar molecules by enzymes. The end products are various types of HFCS. They contain different percentages of glucose, fructose, left-over polysaccharides and some other sugar compounds.



Glucose
Chemical Formula: $C_6H_{12}O_6$
Molecular Weight: 180.16



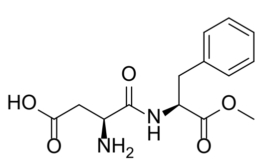
Fructose
Chemical Formula: $C_6H_{12}O_6$
Molecular Weight: 180.16

Notice that glucose and fructose have exactly the same formula and are both carbohydrates. Glucose is an equivalent of aldehyde and fructose equivalent of ketone. Both structures shown here are in their hemi-acetal forms. The key to the sweet taste in these small saccharide molecules is in the hydroxy groups. Because of their unique three-dimensional orientations, these hydroxy groups can interact with the taste receptors for sweetness in our tongues.

Sugar free sweeteners:

Artificial calorie free sweeteners can be very cost effective for the industrial purpose because they are 100 to 1000 times sweeter than the real sugar. Apart from that, people around the world nowadays have a much higher demand for calorie free sweeteners because of the concerns for diabetes and obesities. Here are two sweeteners that are used in Coke Zero® which can mimic the taste of real sugar when used in combination.

- **Aspartame**

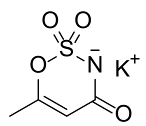


Aspartame
Chemical Formula: $C_{14}H_{18}N_2O_5$
Molecular Weight: 294.31

Aspartame is approved by FDA as an intensive sweetener [18]. Some common commercial names of aspartame-containing sweeteners include Nutrasweet®, Equal®, and Sugar Twin®. One interesting fact about aspartame is that it does contain calories just as sugar - 4 Calories per gram, but because it is about

200 times sweeter than table sugar, consumers are likely to use much less of it. Ever since the discovery of aspartame, there have been numerous studies on the safety of this compound. To this day, aspartame is still considered safe for human consumption. More than 100 regulatory agencies recognize it as a legal food additive.

- **Acesulfame potassium – Ace-K**



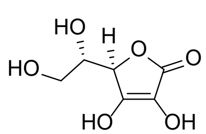
Acesulfame Potassium
Chemical Formula: $C_4H_4NO_4S^-$
Molecular Weight: 162.14

Acesulfame potassium is approved as a non-nutritive sweetener in food. It listed as acesulfame K, acesulfame potassium, or Ace-K food labels. Acesulfame is also about 200 times sweeter than sugar and is indeed calorie free. Human bodies cannot metabolize this compound and generate energy from it. The application of Acesulfame as a food additive is more controversial than aspartame, but so far FDA still considers it safe to use as sweeteners.

3.5 Antioxidants

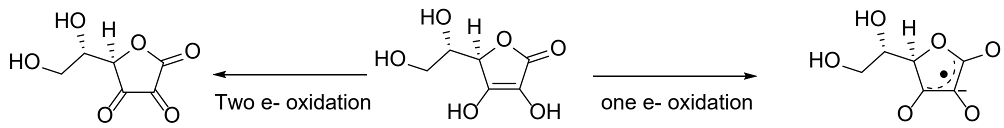
Antioxidants are added to the food to prevent the oxidation of oil and fat molecules and the formation of other rancid compounds. They also help to prevent fresh cut fruits turning brown. The most common antioxidants listed on food labels are: Ascorbic acid, BHA and BHT.

- **Ascorbic Acid – Vitamin C**



Ascorbic Acid- Vitamin C
Chemical Formula: $C_6H_8O_6$
Molecular Weight: 176.12

For humans, vitamin C (ascorbic acid) is an essential vitamin meaning we have to take in this nutrient from dietary sources. The structure of vitamin C features a carboxylic acid and two enols. This makes vitamin C reasonably stable in acid, but susceptible to oxidation under neutral or basic conditions. The oxidation of vitamin C is really fast compared to other chemical reactions, which makes vitamin C a good antioxidant. There are two pathways for vitamin C oxidation: two-electron oxidation and one-electron oxidation. In the two-electron oxidation, vitamin C donates two hydrogen atoms and becomes dehydroascorbate (DHA) as the final product.

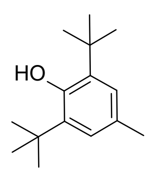


Dehydroascorbate (DHA) Ascorbic Acid Asorbate Free Radical (AFR)

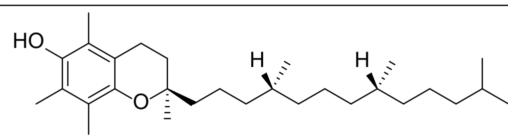
Vitamin C is also a radical scavenger. In the one-electron oxidation, vitamin C is able to form a stable radical. This prevents further radical reactions from happening by disrupting the propagation step.

There is almost no toxicology data associated with Vitamin C, and the LD_{50} oral- rate is as high as 11,900 mg/kg, which is 4 times more than the lethal dosage of table salt. Vitamin C is generally well tolerated in humans. For adults, the recommended daily amount for vitamin C is 65 to 90 mg a day, and the upper limit is a whopping 2,000 mg a day.

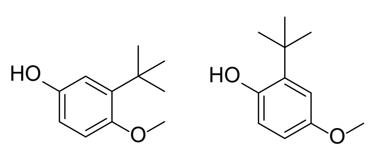
- **BHT- Butylated Hydroxytoluene**
- **BHA- 2-tert-Butyl-4-hydroxyanisole and 3-tert-butyl-4-hydroxyanisole (mixture)**



BHT
Chemical Formula: $C_{15}H_{24}O$
Molecular Weight: 220.36



Vitamin E
Chemical Formula: $C_{29}H_{50}O_2$
Molecular Weight: 430.72



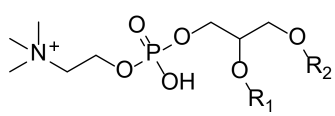
BHA
(mixture of these two)
Chemical Formula: $C_{11}H_{16}O_2$
Molecular Weight: 180.25

Both BHT and BHA can be viewed as derivatives of Vitamin E. They are both phenols, which makes them reductive reagents or antioxidants. The aromatic rings in their structure can stabilize free radicals and, subsequently, stop further radical reactions. But compared to Vitamin E, BHT and BHA have caused much more safety concerns regarding human health. BHT is actually a natural product found in some green algae. Alternatively, the industrial production offers a more economical source. Although BHT has a low acute toxicity (LD_{50} >9 g/kg), it might play a role in causing cancer as implied by some studies. Because of this uncertainty, BHT is labeled as "caution" by Center for Science in the Public Interest. Similarly, BHA is a potential human carcinogen, especially in high doses. At a low intake level such as daily diets, there is no association of BHA with cancer. Nevertheless, BHA is listed as a carcinogen in the State of California.

3.6 Thickeners, stabilizers, emulsifiers

All these reagents are added to foods for their textures. Emulsifiers allow water and oil to remain mixed together to form an emulsion, as in mayonnaise and ice creams. As we discussed in previous chapters, "**Like dissolves like**", water is a very polar bent-shaped molecule while oils are nonpolar compounds which contain long hydrocarbon chains. They do not dissolve in each other. Emulsifiers contain both a hydrophilic head and a hydrophobic tail, just like compounds used in detergents. All emulsifiers work the same way by preventing the small droplets of oil or water from coalescing.

- **Lecithin**

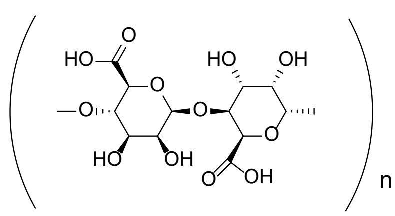


General Structure of Lecithin

R_1, R_2 = Fatty Acid Residue

Lecithin is a natural lipid found in several foods, such as egg yolks, soybeans, nuts, whole grains, as well as in organ meats.

- **Alginic Acid**



As the name suggests, alginic acid exists in the cell walls of a lot of brown algae. It is named as an acid because of its carboxylic acid groups, but it is obvious that it actually belongs to the sugar family. Alginic acid is a polysaccharide.

Both lecithin and alginic acid are considered safe substances. Their LD_{50} listed on SDS are over 5,000 mg/kg. Their names may seem a bit odd, but they are natural substances and have no known toxicity to human if consumed in small quantities.

Thickeners and stabilizers are not real emulsifiers, but they help to improve texture, viscosity, stability and other qualities. They also help to stabilize emulsions. They can be polysaccharides (long chain sugars), collagens (certain types of proteins) or even synthetic cellulose.

3.7 Anti-caking agents

Anti-caking agents are usually inorganic ionic compounds. They can prevent lumping or caking in foods. You can easily spot them on the food labels of powdery or granulated products. Some of the examples of the anti-caking agents are: Calcium aluminum silicate, Calcium phosphate tribasic, Calcium silicate, Magnesium carbonate, Magnesium oxide and Magnesium silicate.

Take Home Messages

To date, people have discovered various food additives, both natural and synthetic. Advancement in chemistry has made food additives part of our life. Without them, the world we know would be different. To raise the awareness of chemical use in food industry would hopefully prompt people to be more vigilant about food safety. Although natural products are generally favored, they are not always safe. For example, natural food dye like cochineal can sometimes cause allergy that leads to life-threatening conditions. The goal of this chapter is to give people a better understanding of food additives listed on the food labels. And make wise choices when it comes to what we eat every day.

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